# Pioneer 10 and 11 Mission Support

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*This article describes significant aspects of the successful Pioneer 10 encounter of the planet Jupiter.*

## I. Encounter Summary

At the time of writing, Pioneer 10 had completed all but 1 week of the 60-day encounter of the plant Jupiter. The Jupiter environment was found to be much more complex and interesting than had been anticipated. The field and particle environment is not simply a dipole field with trapped particles interacting with the solar wind in a semi-static fashion. Tremendous fluctuations in the extent of the bow shock were observed, apparently related to the changes in intensity of the solar wind. Complex structure was observed inside of the bow shock, and a radiation intensity 1000 times higher than is considered lethal to a human being, although the actual magnetic field strength measured was at the lower end of the preflight range of estimates.

Closest approach to Jupiter was reached at 02:25:19 Greenwich mean time on December 4, 1973, at a range of 2.86 Jupiter radii, 203,250 km from the center of the planet (the radius of the visible disk is about 71,000 km), or 132,250 km from the visible surface. The spacecraft appears to have experienced nearly the maximum radiation dose it could take without catastrophic damage to equipment and instruments. Temporary (reversible) damage was experienced in some areas such as in the ultraviolet spectrometry, and mild effects on the radio subsystem were apparent as shifts in the on-board oscillator frequency and receiver rest frequency. The asteroid/meteroid detector appears to have suffered permanent damage in its optics. There was no loss of primary science data due to the radiation effects.

The occultation experiment was successful; an ionosphere was detected on the moon Io, and all data were obtained during the entry and exit phases of the Jupiter occultation. The occultation experiment seeks to determine atmospheric characteristics by ground-based measurement of the effects on the S-band radio link as it transmits through the atmosphere. The Jupiter atmosphere is apparently very complex, and much analysis by the experimenter will be necessary to model the observed effects.

The imaging photopolarimeter returned many intriguing pictures of the planet. The radiation measurements by other instruments peaked at something like 400 million 30-MeV electrons and 4 million 3-MeV protons per square centimeter per second. The temperature measurements showed that the planet radiates about

$2\frac{1}{2}$ times the thermal energy it receives from the Sun and that there is no significant difference between daytime and nighttime temperatures.

## II. Ground System Performance

Besides being the first spacecraft to fly by the planet Jupiter, and the first to utilize nuclear power, the Pioneer mission had another unique aspect which reflected heavily on the ground system: the flying of a complex planetary encounter at a tremendous distance from Earth, and therefore a long round-trip light time, without an on-board flight sequencer. Virtually the entire encounter sequence had to be controlled by ground commands,with a 92-m round-trip light time before the effects of transmitted commands could be observed. Between November 4, the start of Jupiter encounter, and December 14, over 13,000 commands were sent to the Pioneer 10 spacecraft. By DSN count, 1,712 commands were sent on the day of periapsis passage alone, which corresponds to a 44% service rate for the command system, considering that each command is 22 s long and that there are 86,400 s in a day. This means that commands were radiating the day of periapsis about 4 min out of every 9, or a command was transimitted an average of every 50 s the entire day.

The high level of command loading and the potentially serious effect of interruptions in command capability on the encounter sequence were recognized, and the primary activity in preparating the ground system for this encounter was to seek means to improve total command reliability. Improvement of the command system reliability involved making very minor changes in DSN software, but there were no hardware changes. Improvement in reliability came principally from changes in procedures, heavy training activity, and providing maximum redundancy available from the existing implementation. The most important two factors in achieving a significant increase in command reliability were first, getting the Project personnel to use the existing command capabilities in a consistent and optimized mode—i.e., switching from priority commands to timed commands and using command file capabilities in the Mission Control and Computing Center (MCCC) 360/75; and, second and most important, ensuring that all personnel in each element of the Ground Data System understood the importance of command reliability to the success of the mission.

The fruits of the preparation efforts were exceptional ground system reliability during the 60 days of encounter. Prior to the encounter, there had been an interruption to commanding an average of about one every 30 h of heavy command activity. From November 4 to December 20, with the large volume of commanding described, there were only six such interruptions caused by DSN hardware, software, or procedural problems, and, fortunately, none of these failures caused a loss of science data.

A further aspect of the spacecraft design that reflected on ground system reliability was the lack of an on-board data recording system to allow for data playback. The data received in real time at the DSS were the only data acquired. In this regard, the telemetry system reliability performance was also excellent, with only a few minutes of data lost on a single day during encounter (November 9), when several antenna stoppages were experienced.

Therefore, with a statistical sample of one, the capability of having a highly successful planetary encounter using a low-cost spacecraft with limited automatic operation and heavy reliance on ground system reliability was demonstrated.